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**APPLICATION FOR  
UNITED STATES LETTERS PATENT  
SPECIFICATION**

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## TITLE OF THE INVENTION

### LIQUID CRYSTAL DISPLAY DEVICE AND METHOD OF MANUFACTURING THE SAME

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## FIELD OF THE INVENTION

This invention generally relates to a liquid crystal display device and a method of manufacturing the same and, more particularly, to a liquid crystal display device requiring highly accurate dimensions of a photomask pattern designed for the exposure of photoresist and a method of manufacturing such liquid crystal display device.

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## BACKGROUND OF THE INVENTION

A half transparent or hybrid type liquid crystal display (LCD) device includes a thin film transistor (TFT) array substrate, which is, in turn, provided with reflective and transparent display portions. The reflective display portion is generally made of thin film transistors formed on the TFT array substrate, an insulation film covering the thin film transistors and reflective electrodes formed on the insulation film. The transparent display portion is, on the other hand, made of the insulation film and transparent electrodes. The insulation film of the reflective display portion is different in thickness from that of the transparent display portion

to increase the reflectivity and transmittance of the reflective and transparent display portions, respectively. In addition, when the TFT array substrate is put together with a counter substrate, the cell gaps defined in the reflective and transparent display portions are configured to be optimal, respectively. In order to adjust such thickness difference between the reflective and transparent display portions, a photoresist is coated on both the reflective and transparent display portions of the TFT array substrate, the transparent display portion is subjected to an optical exposure treatment, and both reflective and transparent display portions are developed and post-baked.

Since a photoresist with high transmittance is, however, used for the insulation film, it is subjected to reflecting light from an exposure stage during the exposure treatment.

As shown in Fig. 5, an optical exposure stage 210 is provided with recesses 212, which are used to set a TFT array substrate on the exposure stage 210 or to detach it from the stage 210, and plates 214. Although the recesses 212 do not reflect incident light, the plates 214 reflect it as shown by dotted lines and arrows. Thus, portions of an insulation film 128 corresponding to the recesses 212 receive incident light passing through a photomask 208. The other portions of the insulation film 128 corresponding to the plates 214, however, receive not only incident light passing through the photomask 208 but also reflecting light

from the plates 214. Since pattern dimensions depend on receiving quantity of light, patterns of the portions positioned above the recesses 212 are small in width but those of the portions positioned above the plates 214 are wide in width though not shown in different widths in Fig. 5. Such pattern different widths between them cause visibly uneven brightness of images displayed by an LCD device.

## SUMMARY OF THE INVENTION

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It is, accordingly, an object of the present invention to provide an LCD device without such visibly uneven brightness.

It is another object of the present invention to provide an LCD device with improvement of such visibly uneven brightness caused by pattern width difference resulting from receiving quantity of light reflecting from an optical exposure stage.

According to one aspect of the present invention, an LCD device comprises a substrate, thin film transistors formed on the substrate, an insulation film defining first and second regions to cover the thin film transistors, the first and second regions of the insulation film being different in thickness from each other, and light shielding films provided at portions underneath boundaries of the first and second regions.

The LCD device further comprises transparent electrode film formed on the first region, and reflective electrode film formed on the second region.

5           The LCD device is characterized in that the light shielding film is made of the same material as the thin film transistors.

          According to another aspect of the present invention, a  
10   method of manufacturing an LCD device comprises the steps of forming a light shielding film with first and second regions on a substrate, forming a photosensitive insulation film on the light shielding film, and exposing the insulation film to position the light shielding film at boundaries of the first and second regions by using  
15   a photomask.

          The method of manufacturing a liquid crystal display device is characterized in that the step of forming the light shielding film further forms thin film transistors by using the same  
20   material as the light shielding film.

          According to a unique aspect of the present invention, a method of manufacturing a liquid crystal display device comprises the steps of forming any one of reflective, light shielding or  
25   diffusing films on a back surface of a substrate, forming a photosensitive insulation film on a front surface of the substrate,

and exposing the insulation film by using a photomask.

## BRIEF DESCRIPTION OF THE DRAWINGS

5           A more complete appreciation of the present invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed descriptions when considered in connection with the accompanying drawings, wherein:

10           Fig. 1 shows a schematically sectional view of an LCD device in accordance with a first embodiment of the present invention;

15           Fig. 2 is a partial schematic view of a layout of the LCD device shown in Fig. 1;

20           Figs. 3A to 3C are sectional views of components to explain production steps of the LCD device in accordance with the first embodiment of the present invention;

          Figs. 4A to 4C are sectional views of components to explain production steps of the LCD device in accordance with a second embodiment of the present invention; and

Fig. 5 is a schematically sectional view to explain a prior art production step of an LCD device.

## DETAILED EXPLANATION OF THE PREFERRED EMBODIMENTS

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Embodiments of the present invention will be explained below with reference to the attached drawings. It should be noted that the present invention is not limited to the embodiments but covers their equivalents. Throughout the attached drawings, similar or same reference numerals show similar, equivalent or same components. The drawings, however, are shown schematically for the purpose of explanation so that their components are not necessarily the same in shape or dimension as actual ones. In other words, concrete shapes or dimensions of the components should be considered as described in these specifications, not in view of the ones shown in the drawings. Further, some components shown in the drawings may be different in dimension or ratio from each other.

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## FIRST EMBODIMENT

Fig. 1 shows a schematically sectional view of an LCD device in accordance with a first embodiment of the present invention. As shown in Fig. 1, the LCD device includes a thin film transistor (TFT) array substrate 120 and a color filter substrate 140. The TFT array and color filter substrates 120 and 140 are



provided opposite to each other, define a predetermined cell gap supported by spacers 160, and are put together by a sealing material around their peripheral portions. A liquid crystal material injected into the cell gap becomes a liquid crystal layer 180.

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The TFT array substrate 120 includes a transparent glass plate 122, and TFT electrodes 124 and light shielding films 126 formed on the glass plate 122. The TFT electrodes 124 and light shielding films 126 are covered with an insulation film 128. Further, 10 the insulation film 128 is coated with transparent electrodes 130 made of an indium-tin-oxide (ITO) film and reflective electrodes 132 made of a metal film. In order to widen a viewing field for reflecting light, the reflective electrodes 132 are provided with uneven portions. An alignment film (not shown) is coated on the 15 transparent and reflective electrodes 130 and 132.

The light shielding films 126 to be explained later in detail with reference to Fig. 2 are made of such materials that substantially prevent light, which passes through regions of the 20 transparent electrode and reflects from an optical exposure stage to be set forth later with reference to Fig. 3C, from arriving at regions of the reflective electrodes 132. They are preferably of the same materials as those of the TFT electrodes 124 such as molybdenum because the light shielding films 126 are formed in the same 25 process as the TFT electrodes 124.

The light shielding films 126 are disposed at the locations underneath the boundary regions between transparent and reflection regions 134 and 133. The thickness and width of the light shielding films 126 are configured to substantially prevent light, which passes through regions of the transparent electrodes and reflects from the exposure stage, from arriving at regions of the reflective electrodes 132. In other words, the thickness and width of the light shielding films 126 are determined in accordance with a material and light beam radiating conditions, such as light wavelength, frequency, and radiating angle and duration. For example, where such a material and radiating energy are molybdenum and  $300\text{mJ}/\text{cm}^2$ , respectively, the light shielding films 126 are  $0.3\text{ }\mu\text{m}$  to  $10\text{ }\mu\text{m}$  in thickness and preferably about  $6\text{ }\mu\text{m}$  in width.

Fig. 2 shows a partial schematic view of a layout of the LCD device shown in Fig. 1. As shown in Fig. 2, signal lines 202 cross over scanning lines 204 to form a matrix. The transparent and reflective regions 134 and 133 are provided in each element (pixel) of the matrix. Auxiliary capacitor lines 206 are disposed in parallel with the scanning lines 204. As described above, the light shielding films 126 are provided at the locations underneath the boundary regions between the transparent and reflection regions 134 and 133. Thus, the light shielding films 126 are shown in locations between the transparent and reflective regions 134 and 133 in Fig. 2. In short, the light shielding films 126 are provided to surround the

transparent regions 134.

On the other hand, as shown in Fig. 1, the color filter substrate 140 includes color photoresist films 144R (red), 144G (green) and 144B (blue) formed on a transparent glass plate 142. A transparent electrode 146 and is coated with an alignment film (not shown).

Further, there are two different length optical paths by way of the liquid crystal layer 180 through which light passes in response to transparent and reflective display modes of the LCD device shown in Fig. 1, respectively. Namely, when the LCD device carries out the transparent display mode, light from a rear light source 190 passes through the liquid crystal layer 180 once. However, when it carries out the reflective display mode, incident light from color photoresist film 144 passes through the liquid crystal layer 180 and light reflecting from the reflective electrode 132 passes through the liquid crystal layer 180 again. Where the height of the reflective electrode 132 is the same as that of the transparent electrode 130, the optical length of the reflecting light is much longer than that of the light passing through. Thus, in order to obtain optimal optical characteristics in both transparent and reflective display modes, the cell gaps between the transparent electrode 130 and the electrode 146 and that between the reflective electrode 132 and the electrode 146 are necessarily designed to be optimum. The former is bigger than the latter as shown in Fig. 1 to

adjust the optical lengths to be optimum. For that purpose, optical exposure is carried out only for the regions in the substrate on which the transparent electrodes are formed and, then, the substrate is subjected to development and post baking processes..

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A method of manufacturing the LCD device of the first embodiment will be explained with reference to Figs. 3A, 3B and 3C. The method of manufacturing the LCD device is primarily characterized in that the light shielding films 126 are formed on  
10 the glass plate 122 as shown in Fig. 3A, the photosensitive insulation film 128 is further coated on the light shielding films 126 and the glass plate 122 as shown in Fig. 3B and optical energy radiation is carried out only for the transparent regions of the insulation films 128 by using the photomask 208 as shown in Fig.  
15 3C.

As shown in Fig. 3C, the radiating light passes through the recess 212 of an optical exposure stage 210 and travels to the other side of the exposure stage 210. The reflecting light from the  
20 plates 214, on the other hand, travels in the glass plate 122 again but does not reach the insulation film 128 because the light shielding films 126 stop it. Thus, the portions of the insulation film 128 positioned above both the recess 212 and the plates 214 receive substantially the same quantity of light.

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A comparison test has been made for each of the following

LCD devices: (1) the first embodiment LCD device provided with patterns of the thick and thin portions of the insulation film underneath the transparent and reflective electrodes 130 and 132, respectively, and with the light shielding films 126 formed around the transparent regions 134, and (2) a prior art LCD device provided with patterns of the thick and thin portions of the insulation films underneath the transparent and reflective electrodes, respectively, but with no light shielding films. As a result, 70% uneven display has been visibly recognized for the prior art LCD device but no uneven display has been visibly recognized for the first embodiment LCD device.

Since, as described above with respect to the first embodiment, the receiving quantity of light is substantially equal for both portions of the insulation film 128 positioned above the recesses 212 and the plates 214, neither the patterns positioned above the recesses 212 become narrow in width nor those above the plates 214 become wide in width. Its structure does not bring about an uneven display

For the sake of simplicity, the TFT electrodes 124 are omitted from the drawings of Figs. 3A to 3C. In order to reduce manufacturing steps, time and costs, it is preferable to form the TFT electrodes 124 at the same time, and by using the same material, as the light shielding films 126.

## SECOND EMBODIMENT

The LCD device according the first embodiment of the present invention prevents an uneven display due to different reflection coefficients at the exposure stage 210 with the light shielding films 126 provided at predetermined locations between the glass plate 122 and the insulation film 128. An LCD device in accordance with a second embodiment of the present invention is, however, provided with a reflective film coated on the back surface of its TFT array substrate to avoid such an uneven display.

The second embodiment LCD device will be explained below with reference to Figs. 4A to 4C. A method of manufacturing the second embodiment LCD device is characterized in that a reflective film 404 is formed on a glass plate 402 as shown in Fig. 4A, a photosensitive insulation film 406 is formed on the glass plate as shown in Fig. 4B, and energy radiation is selectively carried out for transparent regions of the insulation film 406 by using a photomask 420 as shown in Fig. 4C.

Now, the second embodiment LCD device will be explained below in detail. A 400mm x 500 mm glass plate 402 is prepared and a reflective chromium film 404 is uniformly formed on its back surface (Fig. 4A). The film forming and patterning steps similar to those in an ordinary process to form thin film transistors are repeated to form thin film transistors, electrodes, wirings and

pixel electrodes (but such thin film transistors, electrodes, wirings and pixel electrodes are not shown in Figs. 4A, 4B or 4C).

A photosensitive organic insulation film 406 is then  
5 coated on the glass plate 402 on which the thin film transistors, etc. are formed (Fig. 4B). The glass plate 402 provided with the reflective and insulation films 404 and 406 on its dual surfaces, respectively, is loaded on an optical exposure stage 410. The exposure stage 410 is provided with recesses 412 used to set the  
10 glass plate 402 on the exposure stage 410 or to detach it from the stage 410. Light from a light source 422 is radiated only through transparent portions with the photomask 420. The radiated light does not pass through the reflective film 404 but reflects from it. Such reflecting light passes through the glass plate 402 and the  
15 insulation film 406 again and returns to the photomask 420. The quantity of the light passing through, and returning to, the insulation film 406 is substantially the same whether the transparent regions are positioned above the recesses or not. Dimensions or shapes of the uneven portions of the insulation film  
20 406 formed after the exposure and development treatments are substantially the same whether the transparent regions are positioned above the recesses or not. Thus, an uneven display is not visually recognized on the LCD device.

25 Instead of coating the reflective film 404 on the back of the glass plate 402, a light shielding or diffusion film can be

alternatively attached to it to obtain substantially the same effect as in the first embodiment. A light shielding film 404 prevents the light from reaching the exposure stage 410, i.e., the light reflecting from the exposure stage 410 does not return to the insulation film 406 whether the transparent regions are positioned above the recesses or not. Also, the diffusion film diffuses the light traveling to the exposure stage 410. As a result, in either case, the light transmitted from the exposure stage 410 to the insulation film 406 remains substantially the same in quantity whether the transparent regions are positioned above the recesses or not.

After uneven (concave and convex) portions are made on the insulation film 406, reflective and transparent electrodes are formed on the concave and convex portions to define reflective and transparent regions, respectively. It is desirable to use ITO and molybdenum or aluminum films for the transparent and reflective electrodes, respectively. Further, it is also desirable to form much smaller convex and concave portions on the surface of the convex portions so that they diffuse the incident light to widen a viewing angle in the reflective display mode.

With the structure described above, the total receiving quantity of light at the portions positioned above the recesses 412 of the exposure stage 410 is substantially the same as that at the portions positioned above absence of the recesses 412 of the exposure stage 410. Thus, pattern sizes formed on the insulation



film 406 are not different whether such pattern is positioned above the recesses 412 of the exposure stage 410 or not. An uneven display has not been visually recognized in the second embodiment LCD device, either.

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According to the present invention, the receiving quantity of light by a photosensitive resin film from an optical exposure stage is nil or uniform even though an exposure stage includes surface portions with uneven reflection coefficients and an LCD device has uniform brightness or displays.

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